Relationship between Age 1 Yellowstone Cutthroat Trout Abundance and Selenium in the Salt River Drainage

Final Report

By

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April 2020

Abstract
Selenium bioaccumulation can affect development and survival of young trout which can result in reproductive impairment, low recruitment, or recruitment failure when selenium concentrations are high. In the Salt River drainage in southeast Idaho, analysis of Brown Trout population data has been used to show recruitment impacts at high selenium concentrations. In this study, catch of age 1 Yellowstone Cutthroat Trout declined substantially when Brown and Cutthroat Trout whole body dry weight selenium concentrations exceeded 12 mg/kg. Given this, the EPA fish tissue selenium criterion element concentration of 8.5 mg/kg whole body dry weight appears to be protective of Yellowstone Cutthroat Trout populations in the Salt River drainage.

Introduction
Selenium, which is naturally present in in southeast Idaho, is an essential element that can be toxic (Lemly 1996) when dietary requirements are exceeded. Weathering of shales, exposed by mining or in natural outcrops, can release selenium that can then migrate to nearby waterways (Covington et al. 2018). Concentrations of selenium in water sources in the vicinity of the Smoky Canyon Mine began increasing in 1995 and subsequent investigations determined that selenium was being released from the mine site into the environment (FEIS 2020).

A review of impacts of selenium to salmonids shows that the effects occur in the pre-adult life stages (Van Kirk and Hill 2007) and are related to selenium concentrations in eggs (Kennedy et al. 2000). In a small closed population of salmonids in central Idaho, selenium has been suggested to have contributed to a local extirpation (Janz et al. 2010). However, modeling has shown that when survival of individuals is density-dependent, which is often the case with stream-dwelling salmonids (Chapman 1966, Huntsman and Petty 2014), population-level response to toxicant exposure may occur at higher concentrations than predicted based on individual-level toxicity results (Van Kirk and Hill 2007).

Recently, an analysis was conducted to evaluate recruitment of Brown Trout in the Crow Creek drainage of southeast Idaho relative to selenium concentrations found in fish whole body tissue samples (FEIS 2020). The authors stated that excessive selenium bioaccumulation and resulting toxicity that affects development and survival of young trout should be reflected in lower recruitment, as the numbers of age 1 fish present represent reproduction from the previous year. This statement was supported by Janz et al. (2010) who suggested that for selenium, detecting an effect requires monitoring for recruitment failure, which is the logical population-level consequence of reproductive impairment. Brown Trout were analyzed because they have been seen to have lower individual selenium toxicity thresholds (EC_{10} of 20.5 mg/kg egg tissue dry weight [comparable to 14.04 mg/kg whole body dry weight]) than do native Yellowstone Cutthroat Trout (EC_{10} of 28.5 mg/kg egg tissue dry weight) (Covington et al. 2018). Therefore, where both species are present, the non-native Brown Trout can serve as a sensitive surrogate species for the native Yellowstone Cutthroat (FEIS 2020).

Authors stated (FEIS 2020) that above 30 mg/kg whole body dry weight, real effects on populations were observed, as recruitment appeared to decline above this concentration. However, observation of the referenced data show that recruitment may actually start to decline (pass peak recruitment) at 20 mg/kg whole body dry weight and decline to less than 30% of the peak by 30 mg/kg whole body dry weight. The authors (FEIS 2020) also showed that there was a statistically significant reduction in recruitment at selenium concentrations >30 mg/kg whole body dry weight, which they showed was consistent with observations showing a loss of age 1 Brown Trout in Sage Creek and Hoopes Spring sites from 2013 to 2017 (FEIS 2020).

Researchers (FEIS 2020) also hypothesized that recruitment failures in the field likely do not correspond to the laboratory EC_{10}, simply because fish produce hundreds if not thousands of eggs, yet only a small to moderate percentage of those eggs survive. However, they stated (FEIS 2020) that if the number of young fish consistently surviving is diminished when selenium concentrations exceed toxic levels, then it is likely that selenium toxicity is a causal factor in the reduced recruitment of the next year class of fish (Janz et al. 2010). They concluded that although population metrics are somewhat "coarse," one would expect to see lower recruitment if whole body selenium exceeds some critical threshold.

The difference in selenium concentration EC_{10} vs recruitment loss for Brown Trout suggests that Yellowstone Cutthroat Trout recruitment should also be evaluated. Previous modeling (Van Kirk and Hill 2007) indicated that at selenium concentrations below 7.0–10.0 mg/kg whole body dry weight, Yellowstone Cutthroat Trout populations may compensate for increased pre-winter mortality via decreased density-dependent winter mortality and therefore Yellowstone Cutthroat Trout populations will be protected at selenium concentrations not exceeding 7.0 mg/kg whole body dry weight. However, an evaluation of Yellowstone Cutthroat Trout recruitment similar to that recently completed for Brown Trout (FEIS 2020), has not been performed. Therefore, the objective of this analysis was to evaluate existing data to assess whether recruitment of Yellowstone Cutthroat Trout in the Salt River drainage may be impacted in areas of elevated selenium.

Methods

For several years, selenium in fish tissue collections and fish population analysis have been conducted at various sites in the Salt River drainage (Santec 2017). This dataset was used to evaluate Brown Trout recruitment (FEIS 2020) and presents an opportunity to evaluate the effect selenium may be having on Yellowstone Cutthroat Trout recruitment. These multiple-pass removal data, collected using backpack electrofishing, were obtained from Formation Environmental (Sean Covington; Austin Texas), the consulting company which collected the information, in part, to meet the fisheries data collection requirements of the Smokey Canyon Mine's Comprehensive Environmental Monitoring Program Plan. Catch of Yellowstone Cutthroat Trout and/or Brown Trout occurred at 28 sites in the Salt River drainage for which location data were available and where autumn fish population data were collected from 2006 to 2018 including 3 in the Stump Creek drainage, 1 in Tincup Creek, and 24 in the Crow Creek drainage (Figure 1 and Figure 2). Given the multiple years of sampling, this yielded 151 site-year observations (Appendix A).

Data from all sites and all years were grouped to create a length frequency histogram for Yellowstone Cutthroat Trout (Figure 3). Length-frequency analysis (Devries and Frie 1996) was then used to determine approximate age groups. During fall sampling, age 0 Yellowstone Cutthroat Trout are small and not recruited to the gear efficiently enough to conduct estimates. Therefore, no analysis was conducted for age 0 Yellowstone Cutthroat Trout. Trout were considered effectively collected by electrofishing at lengths of 75 mm and longer. Given this and the length frequency analysis, Yellowstone Cutthroat Trout during fall sampling were considered to be age 1 at lengths of 75 to 190 mm (Figure 3).

Selenium concentration results were obtained from the Idaho Selenium Sampling Technical Team lead and age 1 Yellowstone Cutthroat Trout catch for each site-year observation were matched with average Brown and Yellowstone Cutthroat Trout whole body selenium concentration samples for the same site and year. Average Brown and Cutthroat Trout selenium concentration was used because selenium fish tissue analysis protocols (Anonymous 2016) specify fish species to be collected as "…salmonids, preferably all from the predominant species of trout or char in the waterbody." However, protocols also indicate that "Individual protocols or sampling objectives may include the collection of other species." In practice, this means that as Yellowstone Cutthroat Trout numbers decline a comparison of catch vs. selenium concentration may not be possible, as selenium analysis could shift to include mostly or only Brown Trout. This matching resulted in 101 observations where population estimates were conducted in the fall, Cutthroat or Brown Trout were collected, location could be identified, and selenium sampling could be matched to that site and year. Additionally, 7 more site-year observations matched the above criteria except that Selenium samples from the same year and location were not available but where selenium samples were collected, sometimes by a separate entity, in the vicinity during the same year (Appendix A). Adding these observations resulted in 108 population estimate/selenium fish tissue whole body concentration observations. Alternate selenium sampling sites used were always less than two miles upstream from the population monitoring site and no tributaries entered the stream between the selenium sampling location and the population monitoring location.

The number of age 1 Yellowstone Cutthroat Trout present at each site for each year was plotted against average fish tissue selenium concentration for the corresponding site and year. Sites were also grouped for two separate fish population analyses based on selenium in fish tissue. One analysis was done comparing age 1 Yellowstone Cutthroat Trout catch in sites that had fish tissue selenium concentration of < 8.5 mg/kg whole body dry weight (below the EPA fish tissue selenium criterion element), 8.6 – 13.6 mg/kg whole body dry weight, and > 13.6 mg/kg whole body dry weight (exceeding the SSSC proposed whole body criterion which is based on the egg toxicity threshold and corresponding whole body concentrations for Brown Trout, the most sensitive species at the site [FEIS 2020]). A second analysis was done by observing the fish tissue selenium concentration at which age 1 Yellowstone Cutthroat Trout numbers appeared to decline and comparing age 1 Yellowstone Cutthroat Trout catch at sites above and below that selenium concentration.

Results

A scatter plot of age 1 Yellowstone Cutthroat Trout catch vs. corresponding average Brown and Yellowstone Cutthroat Trout whole body selenium concentrations show catch of age 1 Yellowstone Cutthroat Trout ranged from 0 to 83 when fish tissue whole body selenium concentrations are <12 mg/kg whole body dry weight. But, when fish tissue whole body selenium concentrations were >12 mg/kg whole body dry weight, age 1 Yellowstone Cutthroat Trout catch ranged from 0 to 8 (Figure 4). However, a similar scatter plot showed no clear relationship between age 2+ Yellowstone Cutthroat Trout catch vs. corresponding average Brown and Yellowstone Cutthroat Trout whole body selenium concentrations (Figure 5).

When age 1 Yellowstone Cutthroat Trout catch data were grouped by fish tissue selenium concentrations of < 8.5 mg/kg, 8.6 – 13.6 mg/kg, and > 13.6 mg/kg whole body dry weight, there was no significant difference in number of age 1 Yellowstone Cutthroat Trout captured in the first two categories, but the number of age 1 Yellowstone Cutthroat Trout captured was significantly different and lower, based on comparison of 95% confidence intervals, when selenium concentrations exceeded 13.6 mg/kg whole body dry weight (Figure 6).

Age 1 Yellowstone Cutthroat Trout catch data were also grouped for samples where fish tissue selenium was less than or more than 12 mg/kg whole body dry weight, which the scatter plot showed as the dividing point between high and low age 1 Yellowstone Cutthroat Trout catch. The 95% confidence intervals show a significant difference between these two groups (Figure 7).

Discussion

Based on the results of this analysis and Janz et al. (2010) statement that "recruitment failure is the logical population-level consequence of reproductive impairment," it appears that selenium may be impacting juvenile Yellowstone Cutthroat Trout recruitment in sites where selenium in fish tissue is >12 mg/kg whole body dry weight, which is below the Yellowstone Cutthroat Trout EC_{10} level observed by Covington et al. (2018). Alternatively, Brown Trout recruitment does not seem to be highly affected until selenium exceeds 20 - 30 mg/kg whole body dry weight (FEIS 2020), which is above the EC_{10} level for Brown Trout (Covington et al. 2018). One potential explanation for this difference is fish movement. Since selenium impacts to fish are related to the selenium concentration in eggs (Kennedy et al. 2000), spawning runs of non-resident Brown Trout into areas of high selenium could cause numbers of age 1 trout to remain high, even if there was a failure in recruitment for resident fish. Given the information currently available, there is no way to determine if Brown Trout movement may be influencing recruitment of Brown Trout. The effect of recruitment failure on Yellowstone Cutthroat Trout populations (age 2+ Yellowstone Cutthroat Trout) is unclear and may also be masked by fish movement and the effects of density dependent mortality (Van Kirk and Hill 2007) as evidenced by the lack of population failure at selenium concentrations where recruitment failure was evident.

Covington et al. (2018) found that Brown Trout were more sensitive than Yellowstone Cutthroat Trout to effects of high selenium in a laboratory setting and concluded that, "Where both species are present, the non-native Brown Trout can serve as a sensitive surrogate species for the native Yellowstone Cutthroat, which has regionally important implications for future management and monitoring strategies." While that may be the case for individuals, this analysis, when coupled with that of other researchers (FEIS 2020), suggests that in the Salt River drainage, recruitment of wild free-ranging Yellowstone Cutthroat may be affected by selenium at lower concentrations than Brown Trout. This difference could result from a variety of factors such as differential density dependent factors, mortality effects of selenium beyond the 88-day tests conducted by Covington et al. (2018), fish movement, and others. Mortality pressures in natural settings likely differ from conditions in the lab where EC_{10} values are derived and high selenium concentrations may exacerbate natural mortality pressures.

As is often the case for field studies, interpretation of the results of this analysis is difficult because of the number of factors that are unknown or cannot be controlled. In the case of evaluating recruitment failure of Yellowstone Cutthroat Trout or Brown Trout, these important factors include fish movement and an unbalanced design (*i.e.* similar selenium concentrations are grouped in space, rather than being randomly distributed). Both factors and their interaction could influence results. However, while confounding effects may be present, the results suggest that further evaluation and close tracking of age 1 Yellowstone Cutthroat Trout abundance is warranted.

Conclusions

Based on this analysis, it appears that recruitment failure in Yellowstone Cutthroat Trout is occurring in some locations in the Salt River drainage and that this recruitment failure occurs at selenium fish tissue concentrations exceeding 12 mg/kg whole body dry weight, which is a lower concentration than that reported to cause recruitment failure in Brown Trout (FEIS 2020). Therefore, Brown Trout should not be considered to serve as a sensitive surrogate species for the native Yellowstone Cutthroat Trout. Yellowstone Cutthroat Trout recruitment failure appears to occur at fish tissue selenium concentrations > 12 mg/kg whole body dry weight (Figure 4), therefore, the EPA fish tissue selenium criterion element concentration of 8.5 mg/kg whole body dry weight appears to be protective of Yellowstone Cutthroat Trout populations in the Salt River drainage, while the site-specific selenium criteria of 13.6 mg/kg whole body dry weight does not. Results suggest that further evaluation and close tracking of age 1 Yellowstone Cutthroat Trout abundance is warranted.

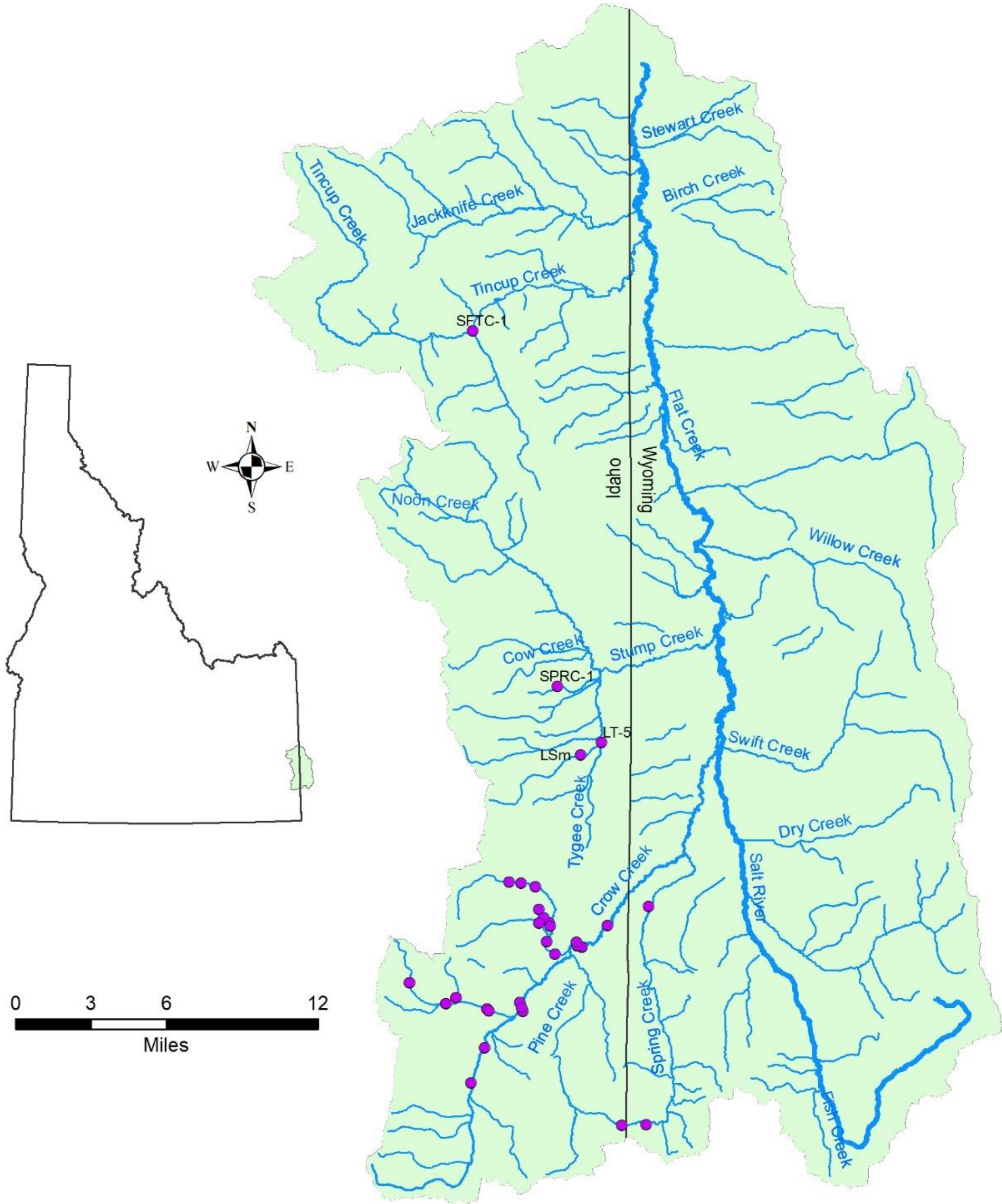

Figure 1. Salt River drainage sites where population estimates were conducted in the fall, Cutthroat or Brown Trout were collected, location could be identified, and selenium sampling could be matched to that site and year.

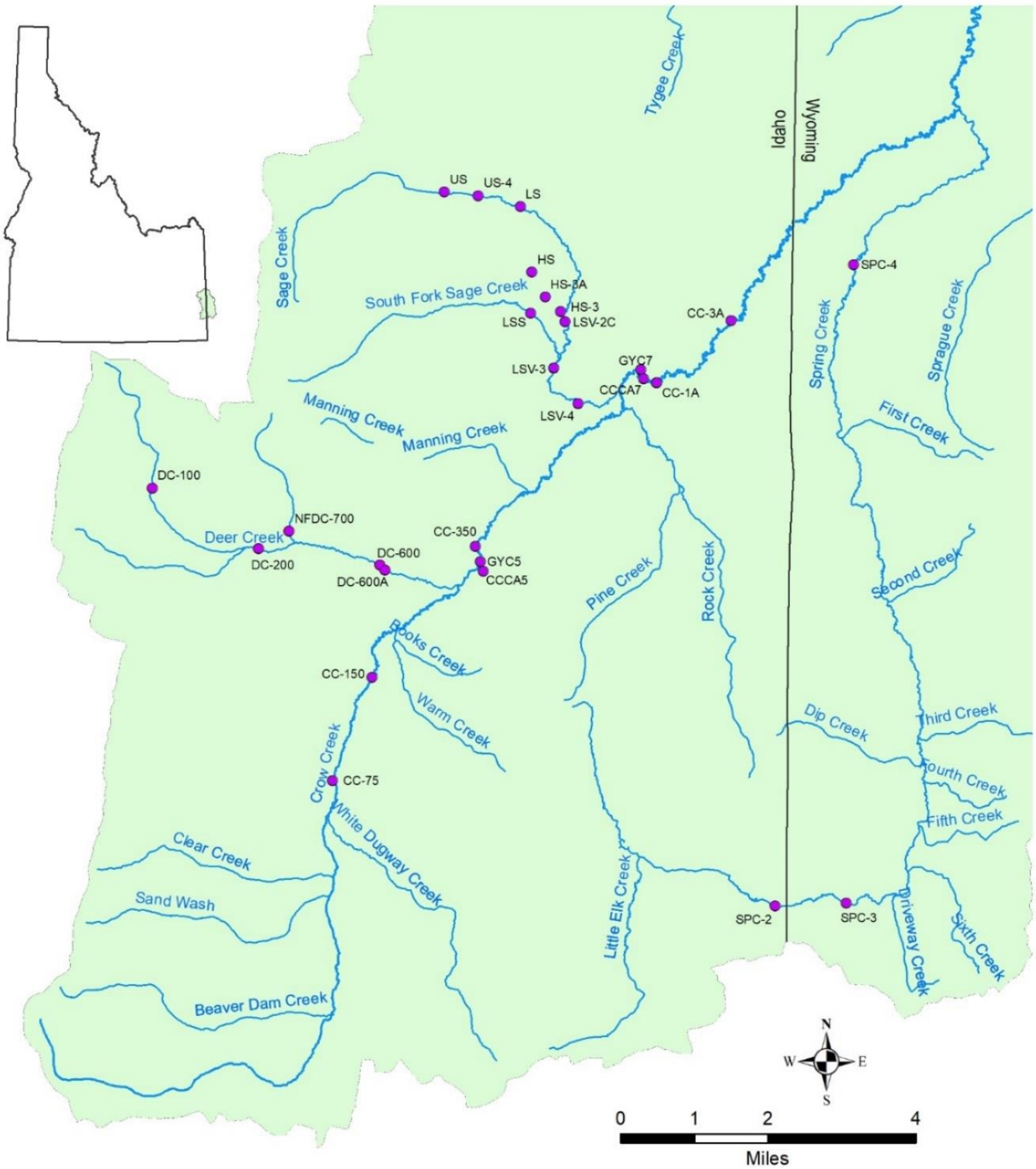

Figure 2. Crow Creek drainage sites where population estimates were conducted in the fall, Cutthroat or Brown Trout were collected, location could be identified, and selenium sampling could be matched to that site and year.

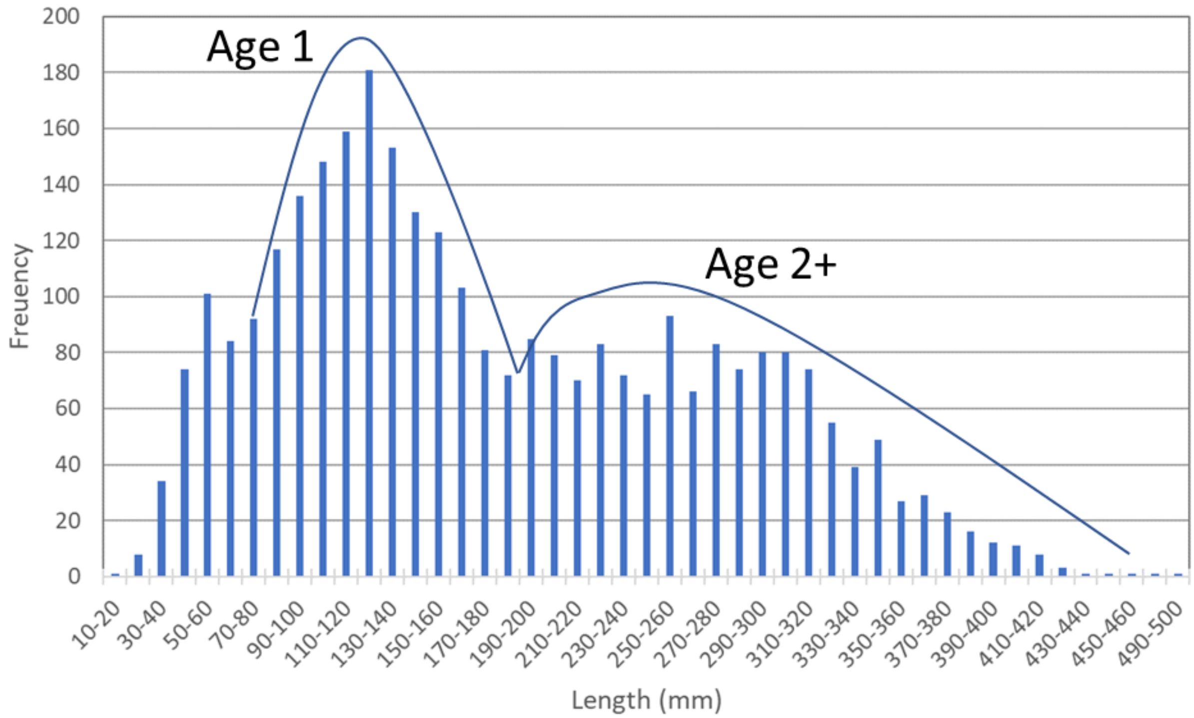

Figure 3. Length frequency histogram for Yellowstone Cutthroat Trout from 28 sites within the Salt River drainage.

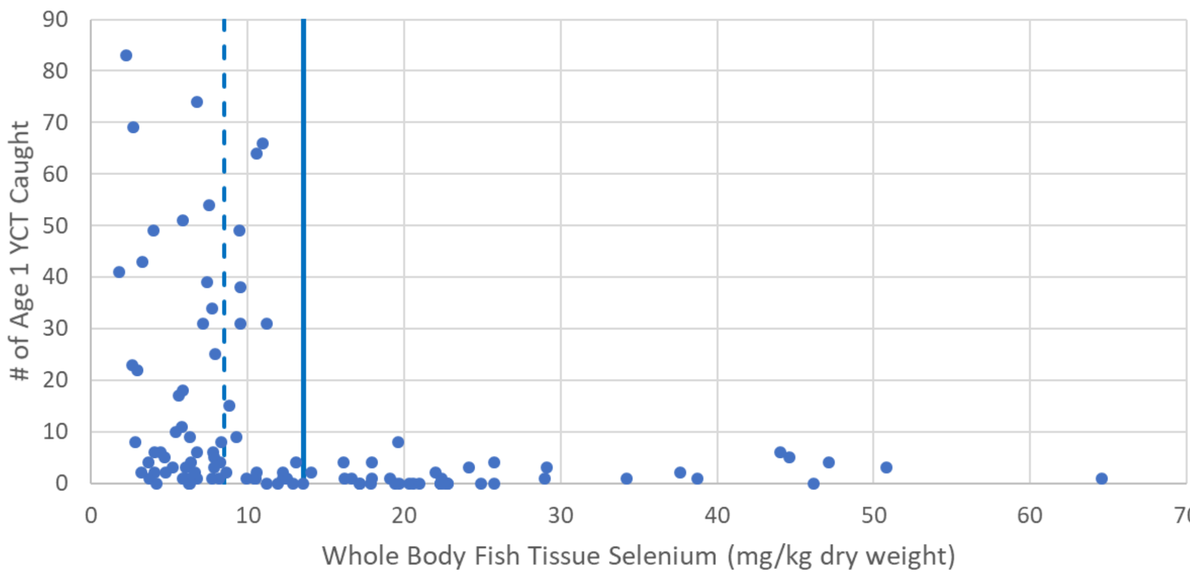

Figure 4. Age 1 Yellowstone Cutthroat Trout catch vs. corresponding average whole body Brown and Yellowstone Cutthroat Trout selenium concentration. The dashed blue vertical line marks the 8.5 mg/kg whole body dry weight EPA fish tissue selenium criterion element and the solid blue vertical line marks the 13.6 mg/kg SSSC proposed whole body dry weight criterion, which is based on the Brown Trout egg toxicity threshold and corresponding whole body concentration (FEIS 2020).

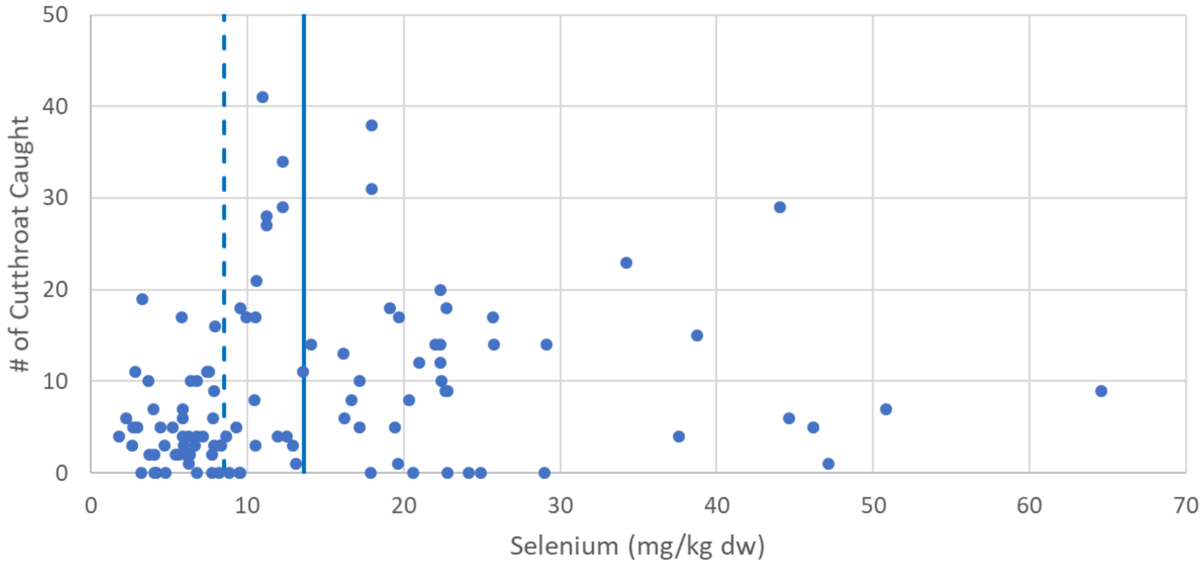

Figure 5. Age 2+ Yellowstone Cutthroat Trout catch vs. corresponding average whole body Brown and Yellowstone Cutthroat Trout selenium concentration. The dashed blue vertical line marks the 8.5 mg/kg whole body dry weight EPA fish tissue selenium criterion element and the solid blue vertical line marks the 13.6 mg/kg SSSC proposed whole body dry weight criterion, which is based on the Brown Trout egg toxicity threshold and corresponding whole body concentration (FEIS 2020).

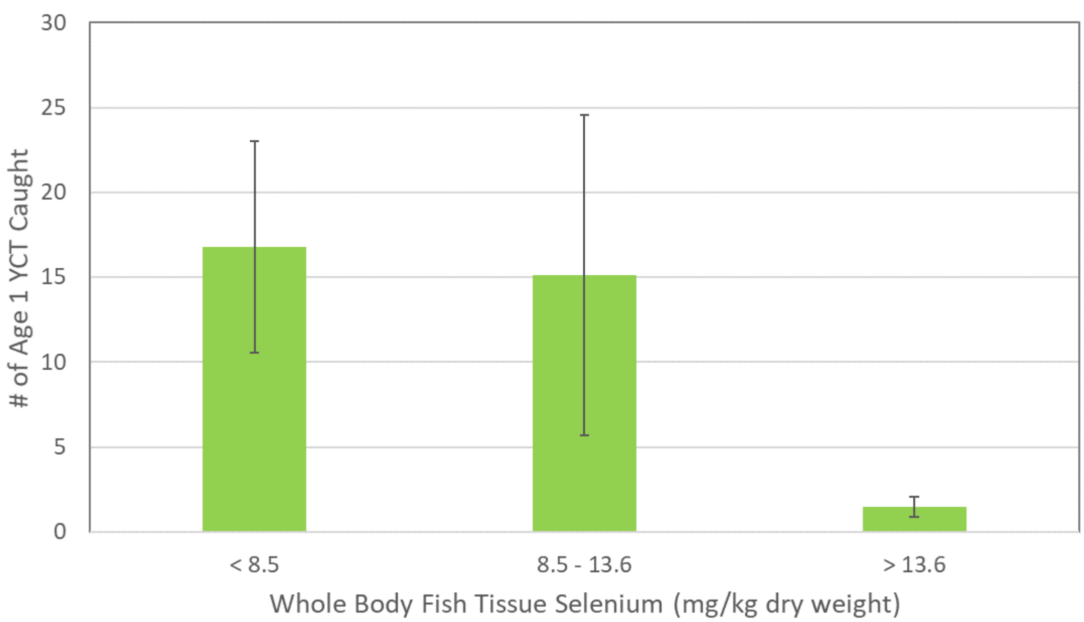

Figure 6. Age 1 Yellowstone Cutthroat Trout catch vs. corresponding average whole body Brown and Yellowstone Cutthroat Trout selenium concentrations grouped by selenium concentrations < 8.5 mg/kg whole body dry weight (below the EPA fish tissue selenium criterion element), 8.6 – 13.6 mg/kg whole body dry weight, and > 13.6 mg/kg whole body dry weight (exceeding the SSSC proposed whole body criterion which is based on the egg toxicity threshold and corresponding whole body concentration which is based on the Brown Trout egg toxicity threshold and corresponding whole body concentration (FEIS 2020).

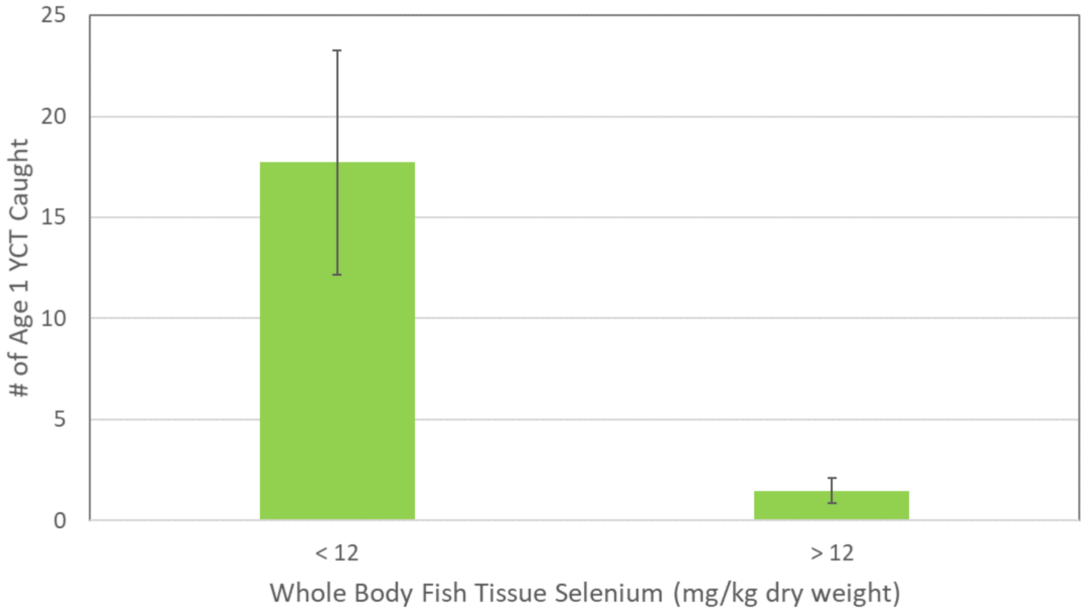

Figure 7. Age 1 Yellowstone Cutthroat Trout catch vs. corresponding average whole body Brown and Yellowstone Cutthroat Trout selenium concentrations grouped by selenium concentrations < or > 12.0 mg/kg whole body dry weight, the concentration at which catch declines substantially (Figure 4).

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Appendix A.

Catch of age 1 Yellowstone Cutthroat Trout, age 2+ Yellowstone Cutthroat Trout, and mean Brown and Yellowstone Cutthroat Trout selenium concentration (whole body dry weight; NS = no sample collected) at sites where Yellowstone Cutthroat Trout and/or Brown Trout were collected, where location data were available, and where autumn fish population data were collected from 2006 to 2018.

Site	Year	Stream	Catch of Age 1 Cutthroat	Catch of Age 2+ Cutthroat	Mean Brown and Yellowstone Cutthroat Trout Selenium conc.	Alternate Site[1]
CC-150	2006	Crow Creek	1	4	5.83	
CC-150	2007	Crow Creek	3	5	5.20	
CC-150	2008	Crow Creek	5	9	7.83	
CC-150	2009	Crow Creek	0	4	6.23	
CC-150	2010	Crow Creek	4	10	6.35	
CC-150	2011	Crow Creek	1	10	6.74	
CC-150	2014	Crow Creek	0	3	NS	
CC-150	2017	Crow Creek	0	2	6.32	
CC-1A US	2016	Crow Creek	0	4	NS	
CC-1A	2006	Crow Creek	1	3	10.51	
CC-1A	2007	Crow Creek	1	17	9.95	
CC-1A	2008	Crow Creek	2	14	14.03	
CC-1A	2009	Crow Creek	2	21	10.59	
CC-1A	2010	Crow Creek	2	34	12.25	
CC-1A	2011	Crow Creek	1	29	12.24	
CC-1A	2012	Crow Creek	4	38	17.96	GYC7 (~ 5000 ft upstream)
CC-1A	2013	Crow Creek	2	14	22.02	
CC-1A	2014	Crow Creek	1	17	NS	
CC-1A	2015	Crow Creek	0	15	NS	
CC-1A	2016	Crow Creek	0	14	22.35	CCCA7 (~ 5000 feet upstream)
CC-1A	2017	Crow Creek	1	8	16.67	
CC-1A	2018	Crow Creek	0	18	22.70	
CC-350	2006	Crow Creek	1	1	6.28	
CC-350	2007	Crow Creek	11	17	5.78	
CC-350	2008	Crow Creek	25	16	7.95	
CC-350	2009	Crow Creek	18	6	5.84	
CC-350	2010	Crow Creek	39	11	7.38	
CC-350	2011	Crow Creek	8	3	8.33	
CC-350	2012	Crow Creek	3	3	7.89	GYC5 (~ 2000 ft upstream)
CC-350	2013	Crow Creek	6	6	7.82	
CC-350	2014	Crow Creek	5	8	NS	
CC-350	2015	Crow Creek	5	5	NS	

Site	Year	Stream	Catch of Age 1 Cutthroat	Catch of Age 2+ Cutthroat	Mean Brown and Yellowstone Cutthroat Trout Selenium conc.	Alternate Site[1]
CC-350	2016	Crow Creek	4	3	8.23	CCCA5 (~ 2000 ft upstream)
CC-350	2017	Crow Creek	2	4	8.64	
CC-350	2018	Crow Creek	1	3	5.95	
CC-3A	2006	Crow Creek	1	8	10.44	
CC-3A	2007	Crow Creek	0	27	11.25	
CC-3A	2008	Crow Creek	0	17	19.68	
CC-3A	2010	Crow Creek	0	20	12.25	CC-1A (~ 4000 ft upstream)
CC-3A	2012	Crow Creek	1	31	17.96	GYC7 (~ 9000 ft upstream)
CC-3A	2013	Crow Creek	0	9	22.78	
CC-3A	2014	Crow Creek	0	10	NS	
CC-3A	2015	Crow Creek	0	5	NS	
CC-3A	2016	Crow Creek	0	12	22.35	CCCA7 (~ 9000 ft upstream)
CC-3A	2018	Crow Creek	0	14	25.74	
CC-75	2006	Crow Creek	2	0	4.05	
CC-75	2007	Crow Creek	2	0	3.18	
CC-75	2008	Crow Creek	2	3	6.60	
CC-75	2009	Crow Creek	3	2	6.07	
CC-75	2010	Crow Creek	17	2	5.58	
CC-75	2011	Crow Creek	6	4	6.76	
CC-75	2014	Crow Creek	2	4	NS	
CC-75	2017	Crow Creek	1	4	NS	
DC-100	2009	Deer Creek	1	0	8.18	
DC-100	2010	Deer Creek	1	0	7.71	
DC-100	2011	Deer Creek	4	0	NS	
DC-100	2014	Deer Creek	23	0	NS	
DC-100	2017	Deer Creek	9	2	6.33	
DC-200	2009	Deer Creek	31	4	7.15	
DC-200	2010	Deer Creek	74	0	6.75	
DC-200	2011	Deer Creek	34	2	7.71	
DC-200	2014	Deer Creek	13	17	NS	
DC-600	2006	Deer Creek	54	11	7.50	
DC-600	2007	Deer Creek	51	7	5.85	
DC-600	2008	Deer Creek	64	17	10.54	
DC-600	2009	Deer Creek	31	18	9.54	
DC-600	2010	Deer Creek	66	41	10.96	
DC-600	2011	Deer Creek	31	28	11.20	
DC-600	2014	Deer Creek	8	2	NS	
DC-600A	2017	Deer Creek	9	5	9.26	
HS	2006	Sage Creek	0	0	NS	
HS	2007	Sage Creek	0	0	24.90	

Site	Year	Stream	Catch of Age 1 Cutthroat	Catch of Age 2+ Cutthroat	Mean Brown and Yellowstone Cutthroat Trout Selenium conc.	Alternate Site[1]
HS	2008	Sage Creek	0	0	22.80	
HS-3	2006	Sage Creek	0	0	20.60	
HS-3	2007	Sage Creek	0	0	17.89	
HS-3	2008	Sage Creek	1	0	28.97	
HS-3	2010	Sage Creek	8	1	19.63	
HS-3	2011	Sage Creek	3	0	24.12	
HS-3	2012	Sage Creek	9	8	NS	
HS-3	2013	Sage Creek	2	4	37.61	
HS-3	2014	Sage Creek	1	1	NS	
HS-3	2015	Sage Creek	11	0	NS	
HS-3	2016	Sage Creek	18	0	NS	
HS-3	2017	Sage Creek	5	6	44.60	
HS-3	2018	Sage Creek	4	1	47.14	
HS-3A	2016	Sage Creek	0	2	NS	
HS-3A	2017	Sage Creek	3	7	50.80	
HS-3A	2018	Sage Creek	1	9	64.58	
LS	2009	Sage Creek	10	2	5.39	
LS	2010	Sage Creek	49	7	3.99	
LS	2011	Sage Creek	32	9	NS	
LS	2014	Sage Creek	23	10	NS	
LS	2017	Sage Creek	20	1	NS	
LSm	2010	Sage Creek	2	0	4.76	
LSS	2009	Sage Creek	0	3	12.91	
LSS	2010	Sage Creek	0	4	11.95	
LSS	2011	Sage Creek	1	4	12.53	
LSS	2014	Sage Creek	1	11	NS	
LSS	2017	Sage Creek	0	5	17.19	
LSV-2C DS	2016	Sage Creek	2	1	NS	
LSV-2C	2006	Sage Creek	0	5	19.45	
LSV-2C	2007	Sage Creek	0	9	22.67	
LSV-2C	2008	Sage Creek	0	12	20.96	
LSV-2C	2009	Sage Creek	0	8	20.32	
LSV-2C	2010	Sage Creek	4	13	16.11	
LSV-2C	2011	Sage Creek	0	10	17.16	
LSV-2C	2012	Sage Creek	1	27	NS	
LSV-2C	2013	Sage Creek	3	14	29.12	
LSV-2C	2014	Sage Creek	2	12	NS	
LSV-2C	2015	Sage Creek	3	8	NS	
LSV-2C	2016	Sage Creek	7	15	NS	
LSV-2C	2017	Sage Creek	4	17	25.73	

Site	Year	Stream	Catch of Age 1 Cutthroat	Catch of Age 2+ Cutthroat	Mean Brown and Yellowstone Cutthroat Trout Selenium conc.	Alternate Site[1]
LSV-2C	2018	Sage Creek	6	29	44.04	
LSV-3	2010	Sage Creek	0	11	13.55	
LSV-4	2006	Sage Creek	1	6	16.20	
LSV-4	2010	Sage Creek	1	18	19.08	
LSV-4	2011	Sage Creek	1	10	22.42	
LSV-4	2012	Sage Creek	3	23	NS	
LSV-4	2013	Sage Creek	1	15	38.73	
LSV-4	2014	Sage Creek	0	3	NS	
LSV-4	2015	Sage Creek	0	2	NS	
LSV-4	2016	Sage Creek	1	8	NS	
LSV-4	2017	Sage Creek	0	5	46.15	
LSV-4	2018	Sage Creek	1	23	34.22	
LT-5	2010	Stump Creek	5	3	4.71	
NFDC-700	2009	Deer Creek	38	0	9.57	
NFDC-700	2010	Deer Creek	49	0	9.50	
NFDC-700	2011	Deer Creek	15	0	8.83	
NFDC-700	2014	Deer Creek	35	3	NS	
NFDC-700	2017	Deer Creek	4	1	13.09	
SFTC-1	2007	Tincup Creek	83	6	2.25	
SFTC-1	2008	Tincup Creek	23	3	2.64	
SPC-2	2009	Spring Creek	41	4	1.76	
SPC-2	2010	Spring Creek	69	5	2.69	
SPC-2	2011	Spring Creek	10	8	NS	
SPC-2	2014	Spring Creek	1	6	NS	
SPC-2	2017	Spring Creek	8	14	NS	
SPC-3	2009	Spring Creek	22	5	2.94	
SPC-3	2010	Spring Creek	43	19	3.25	
SPC-3	2011	Spring Creek	13	18	NS	
SPC-3	2014	Spring Creek	13	11	NS	
SPC-3	2017	Spring Creek	4	1	NS	
SPC-4	2009	Spring Creek	1	2	3.71	
SPC-4	2010	Spring Creek	8	11	2.81	
SPC-4	2011	Spring Creek	1	6	NS	
SPC-4	2014	Spring Creek	0	5	NS	
SPC-4	2017	Spring Creek	6	5	4.42	
SPRC-1	2011	Sage Creek	14	6	NS	
SPRC-1	2015	Sage Creek	0	0	4.21	
US	2010	Sage Creek	4	10	3.68	
US-4	2010	Sage Creek	6	2	4.03	

[1] Alternate Site used for selenium analysis paired with a nearby downstream population estimate site